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Tuesday, April 15, 2008

Gas stations grant real options

Imagine if the only place you could refill your gas tank was at home, so that you could never choose to drive farther than one tankful of gas would carry you. Furthermore, imagine that it usually required most of a tankful to get from one place you want to go to another -- or to get back home. So you usually could choose to go only one place per trip, and even when you could go more than one place, you had to plan the entire trip well ahead of time and could not deviate from it, no matter how much your needs changed while on the trip.

That is largely the situation with space operations today. You have to plan the entire mission ahead of time. If in mid-mission you discover that you want to change the plane of your orbit, or extend the life of your satellite, or make any other change that requires more propellant than you long ago planned for, you are out of luck. If you want to reserve a wide variety of such decisions instead of committing to the entire plan up-front, it won't happen unless you launch a great deal of extra propellant that you will probably never use.

Refueling capabilities and orbital propellant depots can change that. They provide choices -- what economists call *real options*.

Like financial options, in an uncertain world real options often have substantial value. The kinds of real options commonly encountered in the business world include input mix options (options to use different inputs to deliver the substantially same output), output mix options (to use the same inputs to deliver different outputs), termination options (to abandon early failing projects or projects that have become unimportant), intensity or scale options (options to increase or decrease output), options to stop and restart, and switching options (the option to abandon one mean or end and change to another). All of these options can have a substantial operational and financial value that is not captured by traditional analysis of fixed plans.

Propellant depots don't provide substantially cheaper propellant: it must all, for the near future, still be launched quite expensively from earth. And propellant depots don't provide an infinite variety of choices. They won't make it affordable for astronauts headed for Mars to return back home when they discover that they forgot to pack their toothbrushes. Orbital mechanics is relentless and an option to take on extra, but still expensive, propellant can only change things so much, and you especially won't be able to afford such an option if you're off the beaten path. But propellant depots and refuelable satellites will allow those operating satellites in common orbits, such as geosynchronous orbit and low polar earth orbit, to change plans during a satellite's lifetime by adding a wide variety of valuable real options, for example:

* Spy satellites have highly uncertain propellant usage, and often end their lifetimes mostly full of propellant or exhaust their

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Nick Szabo

"A premier thinker about history, law and economics, and the lessons they have for security." -- Adam Shostack, Emergent Chaos

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"Like most blogs worth my attention, this blog is updated only infrequently. That is because the authors of blogs worth my attention only post when they have something to say that is true, relevant and not already known by their audience. Most of the human race does not have the skill to know when an idea has these three properties. The skill is particularly rare in the fields of politics and economics, which is why this blog is such a rare and valuable thing." -- Richard Hollerith

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propellant long before any other components have degraded. Propellant depots will give spy satellites real options to optimize time over certain targets, to avoid a variety of attacks by changing orbits, and add flexibility to respond to other unpredictable challenges.

* Commercial satellites: depots will extend the lifetimes of satellites that prove to be important, and allow satellites to be relocated over new locations as markets change. (With a few extra features on a depot tanker, propellant already on board a broken satellite, or a satellite that has proved to be unimportant, might be "siphoned" back into the tanker and used on a working and important spacecraft).

* Upper stages and satellites can be checked out to make sure they are in working order on orbit before being fueled. Immediate systems failure, which is a common failure mode, need no longer result in the waste of expensive propellant.

This short list is probably the tip of the iceberg. Real options are about the unpredictable, and it's hard to make a list of the unpredictable ahead of time. On-orbit refueling and orbital propellant depots are not just a technology, they are part of a new paradigm. They are part of thinking of space activities in terms of real options instead of fixed plans. This paradigm recognizes uncertainties in space missions and businesses that traditonal fixed space planning has neglected. Making good use of propellant depots requires not only technology, but the recognition of these uncertainties, and as a result a recognition of the options that businessmen, militaries, and scientists would like to retain. Those options can then be brought to reality with refuelable satellites and orbital depots, quite possibly in association with other technologies that enhance mission flexibility in other ways. It's not propellant depots and refueling capabilities by themselves that will be beneficial, it will be their use to enable a wide variety of new and valuable real options for spacecraft operators and users. It will be a crucial and lucrative entrepreneurial task to identify these real options and enable them with refuelable satellites, depots, and probably a wide variety of other techniques and services.

Going back to our humble earthbound example, real options explain why most commuters prefer cars (with gas stations available in a wide variety of locations) to mass transist. Mass transist resembles far more the fixed plan -- travel from home to work and back every day, and that's it. Under the fixed-plan assumption, mass transit is far less expensive and far more energy-efficient than automobiles. Cars, and the gas stations that refuel them, provide real options -- to pick up kids from baseball today, to go to a class after work tommorrow, to go shopping at one of a wide variety of stores, to visit your doctor or the emergency room when you get sick, to pick up your friend from the airport after work the next day, and so on. Mass transit and traditional space mission planning both represent the mentality of artificial certainty, the idea that we can simply plot out the future and it will come to fruition just so. At least space mission planners have the excuse of orbital mechanics, which is highly predictable. Human beings are not, nor are the vast variety of our needs and desires known to planners. Economic comparisons between mass transit and automobiles that don't account for the vast number and variety of options made real by the the latter will grossly underestimate the value of automobiles.

Related:

Real options analysis also allows planning for discontinous risk, rather than the artificial assumption that risk is a continuous function that can be modeled simply by adding a risk premium to a risk-free interest rate. More on that, and the implications for space mission evaluation, here.

Here is an introduction to mathematical analysis of real options, and here is a discussion of orbital depots for propellants that turn into vapors at normal temperatures, and are thus hard to store.

Posted by Nick Szabo at 11:18 AM

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2 comments:

Byrne said...

A few other points to consider:

Will the accumulation of assets as real options, versus the use of those assets for their discounted cash flow, slow down economic growth as economic volatility (and thus the volatility premium on those assets) increases?

Real options compound in value: one refueling depot allows you to move within the fuel-tank range of that depot, but another depot within range means that your movement is bounded by how much fuel you can afford to buy -- so activity is increasingly defined by the marginal cost of staying in orbit, rather than the fixed cost of getting there.

I would expect an easy analogy to be the growth of coal stockpiles in colonies (I know this happened in SE Asia, and I'm sure that wasn't the only place). Modern finance could allow derivatives to make this sort of project happen at a more sensible pace than before -- the first coaling station radically increases the value of future ones, so the first actor has to either accept a low fraction of the total value he creates, or make a huge initial investment. With derivatives, one could bet on future fueling depot construction (e.g. a contract that paid out $X per station per year over the next ten years -- you'd buy the contract, launch your first depot, then sell the contract once the estimated future number of depots increased).

This is a very interesting subject. I've tried to figure out how the economy will look when going long volatility is the best way to make money -- in a Singularity context, this would be because the resource that increases wealth (spare computing cycles) also increases its own utility -- so the very richest are also earning the highest returns. In that context, the only way for a poor person to get rich is to create volatility and hope said volatility works out in his favor. Since most of someone's assets would be real options of one kind or another, they'd expect a higher net worth from, say, a $20 trillion US GDP that had growth between -10% and 5% than from a $30 trillion GDP with expected growth between 4% and 8%.

1:18 PM

nick said...

another depot within range means that your movement is bounded by how much fuel you can afford to buy -- so activity is increasingly defined by the marginal cost of staying in orbit, rather than the fixed cost of getting there.

Only true where materials native to space are used. Otherwise, the propellant you can afford to buy is also bounded by the cost of getting there. Nevertheless, even without native materials the value of propellant-related real options increase with the density of depots, possibly in a nonlinear fashion. But depots by themselves are insufficient -- the real option is really a tuple {interesting place to go, propellant to get there}. So the increase in valuable places to go, alternative things to do (like the long list of options now available to the car driver I discussed above) in a given orbital region is a crucial part of this growth.

...one could bet on future fueling depot construction (e.g. a contract that paid out $X per station per year over the next ten years -- you'd buy the contract, launch your first depot, then sell the contract once the estimated future number of depots increased).

I'm not sure I follow this. Who is the counterparty -- somebody selling insurance against competition? Has anybody done this historically? It's an interesting idea.

Perhaps one could arbitrage between competitors. Sell insurance to A against A losing too much market share, and to B against B failing to gain enough market share (for a given level of investment towards such growth), with the insurance company winning in the more likely case that B gains more than the insured amount of market share but A does not lose enough market share to go below their insured amount. Indeed, spread the market share risk across enough companies and the insurance company always wins (but so do all the companies through lower risk from competition). The usual problems of adverse selection and moral hazard arise, though.

If this was going to work, somebody would already have made it work, I suspect. It doesn't require computers. (Both insurance and derivatives were around in late medieval Italy. It's only when you want sophisticated simulations or function-fitting, especially when constructing synthetic assets from multiple derivatives, or when doing real-time arbitrage or hedging that computers are required). Also, in a stock market investors can do a similar kind of risk spreading by diversifying their investments across several competitors.

The most common way for the first mover to protect itself against copycat competition is through property, especially IP, but gaining physical rights over the best native propellant sources would also work well.

Another technique, really one that is crucial for growing networks of real options, is vertical integration. If, for example, you want to sell ethanol, it's no good just to start making ethanol and hope people will come buy it. No, you've got to sign up a large number of gas stations in an area to pump ethanol, and you have to get car companies to sell cars that take ethanol via the dealerships in that area.

Electric companies, back when electricty was not the norm and they were in a free market and actually trying to sell more of their electricity, often sold electric appliances at stores they set up in the same communities to which they were piping electricity, and often gave them away to people who signed up for electricity service. It's no good generating and piping electricity out to houses that have no electric appliances. The real option tuple here is {electricity piped to house, useful electric appliances sold locally}.

Back to space depots, an entrepreneur has to sell the real options they make possible, and has to vertically integrate enough to make sure those real options are delivered. For example to deliver extendable life satellites, one has to sell the satellites to satellite operators (e.g. communications companies) who want this feature, then make the satellites refuelable and implement a depot. Much easier than trying to sell existing comsat makers on the idea that they should sell their own customers on such features, make their own investments in redesiging their satellites to be refuelable, and so on. The space depot entrepreneur should also consider vertical integration into "more places to go" to complete the real option tuples {neat place to go, propellant to get there}.

I've tried to figure out how the economy will look when going long volatility is the best way to make money...the only way for a poor person to get rich is to create volatility and hope said volatility works out in his favor.

By "create volatility" do you mean just bet at long odds, or do you mean something active, like Marxist revolution? :-)

Rich people get lazy and that gives poor people with brains plenty of opportunity to make it rich. Somebody has to program those computers, advise the rich on their investments, heal the rich when they are sick (or just want to live longer), lawyer for the rich when they dispute, and so on. It won't be the fellow rich, they're too busy having fun and then feeling guilty about it and donating to Barack Obama.

6:46 PM

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